# Technical Report Documentation Page

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Investigation of the Comparative Corrosion of Aluminum and Steel Corrugated Metal Pipes in Similar Environments

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Maxwell, W.S. and R.F. Stratfull

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**16. ABSTRACT**

I. Introduction

At the present time the California Standard Specifications specify that only tile, steel and concrete piping may be used for highway drainage structures. Manufacturers are now producing aluminum CMP and the Bureau of Public Roads and the California Division of Highways are cognizant of the possibility of an economic or engineering advantage in the use of the new material.

The test program was initiated on March 31, 1961, under Laboratory Project Authorization 71-R-6244 and the cost is borne by the California Division of Highways and the Bureau of Public Roads. This test will attempt to determine if there are limitations with respect to corrosion and abrasion, on the use of aluminum CMP for highway drainage structures. It should be noted that the test sites contained in this program are among the most corrosive and abrasive to metal culverts that have been found in the experience of the California Division of Highways.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

# INVESTIGATION OF THE COMPARATIVE CORROSION OF ALUMINUM AND STEEL CORRUGATED METAL PIPES IN SIMILAR ENVIRONMENTS

September 1962

62-15

State of California
Department of Public Works
Division of Highways
Materials and Research Department

September 1962

Mr. F. N. Hveem
Materials & Research Engineer
Division of Highways
Materials and Research Department
Sacramento, California

Lab. Proj. Auth.
71-R-6244

Dear Mr. Hveem:

Submitted for your information is the first progress report on an:

INVESTIGATION OF THE COMPARATIVE CORROSION

OF

ALUMINUM AND STEEL CORRUGATED METAL PIPES

IN SIMILAR ENVIRONMENTS

Study made by . . . . . . . . . . . . . Structural Materials Section
Under the direction of. . . . . . . . . . . . . . . . . J. L. Beaton
Work Supervised by. . . . . . . . . . . . . . . . . . R. F. Stratfull
Report prepared by. . . . . . . W. S. Maxwell and R. F. Stratfull

Very truly yours,

John L Beaton

J. L. Beaton
Supervising Highway Engineer

WSM/RFS:lk

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# I. INTRODUCTION

At the present time the California Standard Specifications specify that only tile, steel and concrete piping may be used for highway drainage structures. Manufacturers are now producing aluminum CMP and the Bureau of Public Roads and the California Division of Highways are cognizent of the possibility of an economic or engineering advantage in the use of the new material.

The test program was initiated on March 31, 1961, under Laboratory Project Authorization 71-R-6244 and the cost is borne by the California Division of Highways and the Bureau of Public Roads. This test will attempt to determine if there are limitations with respect to corrosion and abrasion, on the use of aluminum CMP for highway drainage structures. It should be noted that the test sites contained in this program are among the most corrosive and abrasive to metal culverts that have been found in the experience of the California Division of Highways.

## II. CONCLUSIONS

A. At the abrasion test site, the following conclusions appear warranted:

1. The aluminum pipe is not as abrasion resistant as the steel, and cannot be considered as an equal to steel in this respect.

2. Rivets should be placed in the valleys of the corrugations for all pipe no matter what material is used in its fabrication.

3. Asphalt is better in abrasion resistance as a pipe invert paving material than is concrete.

4. Asbestos bonding improves the abrasion resistance of an asphalt coated pipe.

B. At the corrosion test sites, the following apply:

1. In the locations of acidic soils and waters, the aluminum pipe is not economically superior to steel in corrosion resistance (Neither uncoated steel nor aluminum is satisfactory for use as culvert material at these locations)

2. The comparative corrosion resistance of aluminum to steel at all other sites (see B-1) cannot be determined at this time as both have had a nominal amount of corrosion attack.

## III. ENVIRONMENTAL CONDITIONS

At each test site soil and water samples were obtained and chemically analyzed by the Materials and Research Department. The test results are included on Table 1. From our Test Method No. Calif. 643-A, the soil resistivity and the pH readings were used to determine the relative corrosivity of the test locations.

The abrasion test site was chosen because the reinforced concrete box at this location has required repair of the invert twice in ten years of service.

It should be noted that the test sites utilized in this study are probably the most aggressive sites in which culverts can be exposed.

## IV. INSTALLATION METHODS

All test pipes were installed by the maintenance forces in each District. Generally, the pipes which were installed in the same channel were physically separated by a distance of approximately 3" between the abutting ends. Then a 1/8" thick neoprene gasket was used as an electrical insulating material between the pipe coupler and the pipes. After the neoprene gasket was in place, a bituminous coated steel coupler was installed.

The purpose of the gasket and coated coupler was to prevent galvanic corrosion of the aluminum. When aluminum and steel are electrically connected in an electrolyte such as soil, an electrical current will flow and cause accelerated corrosion of the aluminum. The two test metals were electrically separated by space or mechanical means in all locations except at the abrasion test site (IV-SC1-5-Sta 250+25, Br. #37-165). The pipes were not electrically separated at the abrasion test site as the possibility of galvanic corrosion is considered to be negligible, the reason being that water is present in the culvert only during periods of flow. This is approximately 3 to 6 times per year.

The details of the installation of the test pipes are shown by Exhibits 1 through 11.

## V. CURRENT TEST RESULTS

Several inspections have been conducted at each test location. The results of the last inspection have been noted on Tables 2 and 3.

At the acid ground water test site in II-Sha-3-B, a section of aluminum CMP approximately 5" x 10" was cut from the invert after 56 days of exposure. A photo of this section of aluminum is shown on Exhibit 12 and represents the result of corrosion after 56 days of exposure.

The aluminum culvert in the abrasion test site requires repair due to the excessive metal loss of the rivets. The aluminum section should be repaired with bolts to prevent the loss of the plate. At the abrasion test site the apparent order of abrasion resistance is as follows, with number 1 being the best:

1. Asbestos bonded asphalt paved CMP
2. Asphalt dipped paved invert CMP
3. Galvanized steel CMP
4. Aluminum CMP
5. Concrete

At the corrosion test sites of high acidity, the aluminum did not appear to have better corrosion resistance than steel.

At the alkaline and sea water sites, the aluminum and steel were moderately affected by corrosion. The degree of corrosion has been nominal in both cases and will require additional study.

TABLE 1

TEST RESULTS

| Locations | II-Sha-3-B Nr. Redding | III-But-21-B Nr. Oroville | IV-SC1-5-C Nr. Los Gatos | X-SJ-53-C Nr.Rio Vista Sample 1st | X-SJ-53-C Nr.Rio Vista Sample 2nd | XI-SD-NatCity at Sweetwater Bridge | XI-Imp-187-F at Salton Sea |
|---|---|---|---|---|---|---|---|
| Installation Date | 11-16-61 | 8-21-61 | 10-19-61 | 8-16-61 | | 9-26-61 | 9-29-61 |
| Avg. pH | 3.3 | 2.7 | 7.7 | 4.5 | 6.3 | 8.3 | 7.5 |
| Avg. Resistivity | 650 | 165 | 3500 | 620 | 973 | 39 | 6.5 |
| *Avg. Yrs. | Less than 5 yrs. | Less than 5 yrs. | 49 years | Less than 5 yrs. | 17 yrs. | Less than 5 years | Less than 5 years |
| Na + K (as Na)PPM | 14 | 7 | 65 | | 178 | 12,300 | 99,740 |
| Ca PPM | 44 | 266 | 102 | | 65 | 170 | 12,300 |
| Mg PPM | 88 | 328 | 19 | | 26 | 504 | 2,170 |
| $CO_3$ PPM | Nil | Nil | 204 | | Nil | Nil | Nil |
| $HCO_3$ PPM | Nil | Nil | Nil | | 9 | 170 | 180 |
| CL PPM | Nil | 50 | 516 | | 144 | 14,920 | 41,520 |
| $SO_4$ PPM | 996 | 13,800 | 132 | | 356 | 2,220 | 7,920 |

A1 CMP Made of Alloy Clad MG-11a-H34

Galv. Steel CMP Made of Copper bearing steel with galvanized coating

*Estimated years to perforation of 16 gage steel CMP. Test Method Calif. 643-A

TABLE 2

INSPECTION RESULTS

Observations were made on both the soil and interior surface of the piping. The results of the last inspection are as follows:

| Locations | Installation Date | Date of Last Inspection | Days of Exposure | Results of Last Inspection Aluminum | Results of Last Inspection Steel |
|---|---|---|---|---|---|
| II-Sha-3-B Nr. Redding | 11-16-61 | 4-23-62 | 157 | Perforated Invert | No Perforation |
| III-But-21-B Nr. Oroville | 8-21-61 | 4-24-62 | 266 | Perforated Invert | Perforated Invert |
| X-SJ-53-C Nr. Rio Vista | 8-16-61 | 4-24-62 | 271 | Pit ± .005" in one spot | No rust observed |
| XI-SD-2-Natl.City at Sweetwater Br. | 9-26-61 | 4-30-62 | 215 | Pit approx. .005±" | No rust observed |
| XI-Imp-187-F at Salton Sea | 9-29-61 | 4-30-62 | 212 | Pit approx. .002±" (soil side) | Rust just beginning (soil side) |

TABLE 3

DISTRICT IV INSPECTION RESULTS

AT 187 DAYS OF EXPOSURE

Installation Date 10-19-61
Date of last Inspection 4-25-62

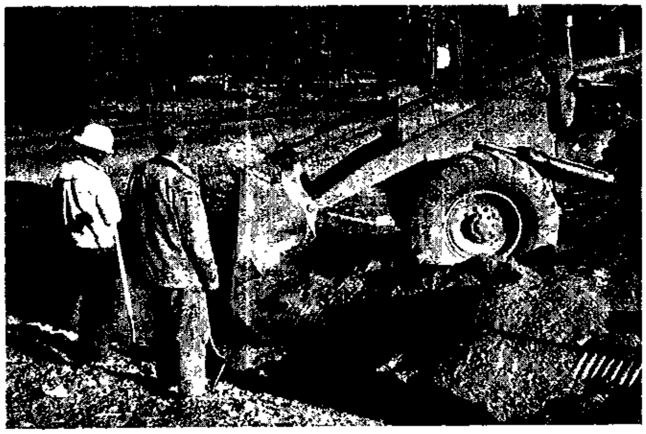
IV-SC1-5-C

| | |
|---|---|
| Concrete (Upstream) | Spalling of upstream concrete floor ± 6" back of original line of concrete. Grooves about ½" deep in concrete floor through the aggregate. |
| Aluminum | Dents about ¼" deep in about 10 locations. Nicks about 1/32" deep in approx. 25 locations. Aluminum rivets have lost approx. ½ of their original metal thickness. Some rivets have severly deformed to the point that the line of demarcation between rivet and culvert metal are hardly visible. There is evidence of plastic flow of the aluminum culvert metal due to abrasion. |
| Galvanized Steel | No dents or noticeable nicks on steel surface. Zinc has been abraded from the steel in some areas. Rounding of upstream surface of rivets, but no structural problems. There is abrasion of steel, but quantity of steel loss cannot be estimated. |
| Asbestos Bonded Paved Invert | Evidence of severe abrasion such as gouging and grooving, etc. No spalling of paving to metal surface. Paving intact as protective coating and no chips of asphalt in the dipped section of the pipe. |
| Asphalt Dip Paved Invert | Chipping of asphalt in dipped section of pipe. Paved invert abraded in several locations, but still satisfactory as a protective coating. |
| Concrete (Downstream) | Downstream concrete abraded about ½" deep in several locations (3 or 4) through the aggregate. |

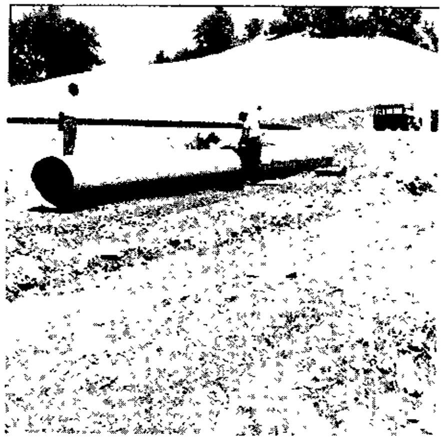
II-Sha-3-B
Rt. of Sta. 265


Excavating backfill for culvert installation.

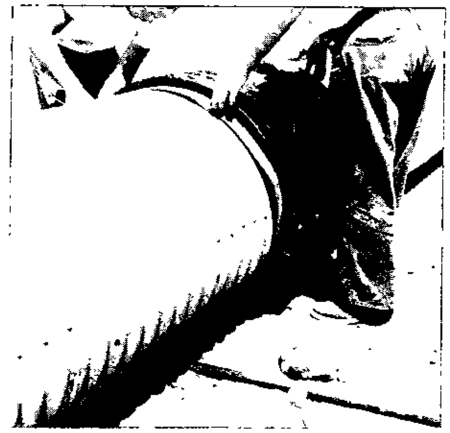
Note neoprene gasket extending past edge of coupler.



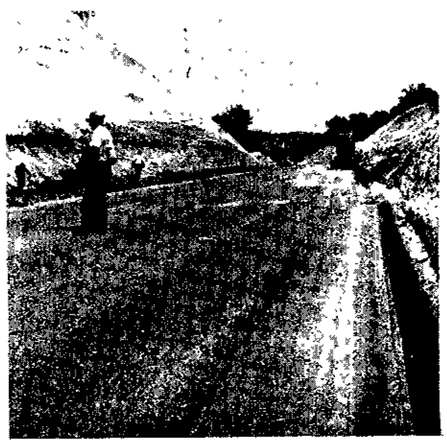
Backfilling over the two CMPs.



Assembling of CMPs in excavated trench



Placing coupler over neoprene gasket



Backfill was obtained from dark areas in face of nearby cut

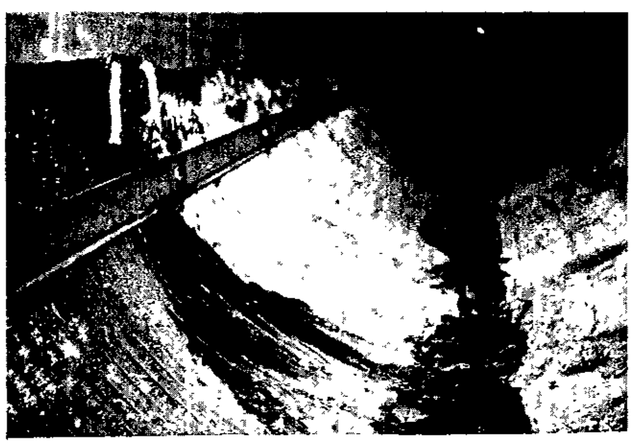
Placing backfill over piping

Backfilling over piping

Completed installation

Bolting walers to walls and floor of RCB for CMP anchoring.

Completed waler installation.



Interior view of completed installation.
Note:

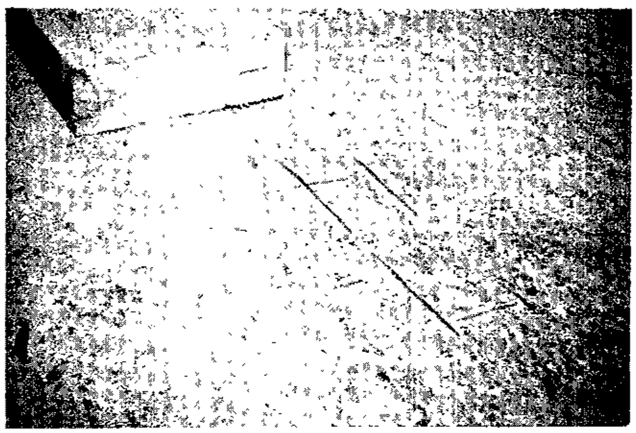
1. Steel channel used to anchor CMP to waler.

2. End of white asbestos rope hanging down at left; at this point is a water-tight lap joint.

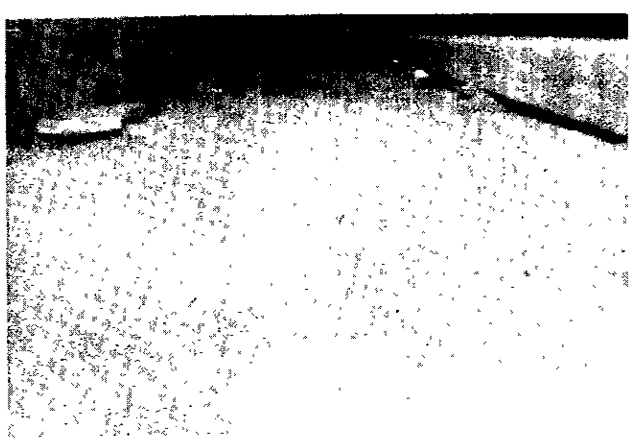
IV-SC1-5-C
Sta. 250+25
Br. #37-165

EXHIBIT 4

Upstream end of RCB



Note roughness
of concrete floor
at end of waler.

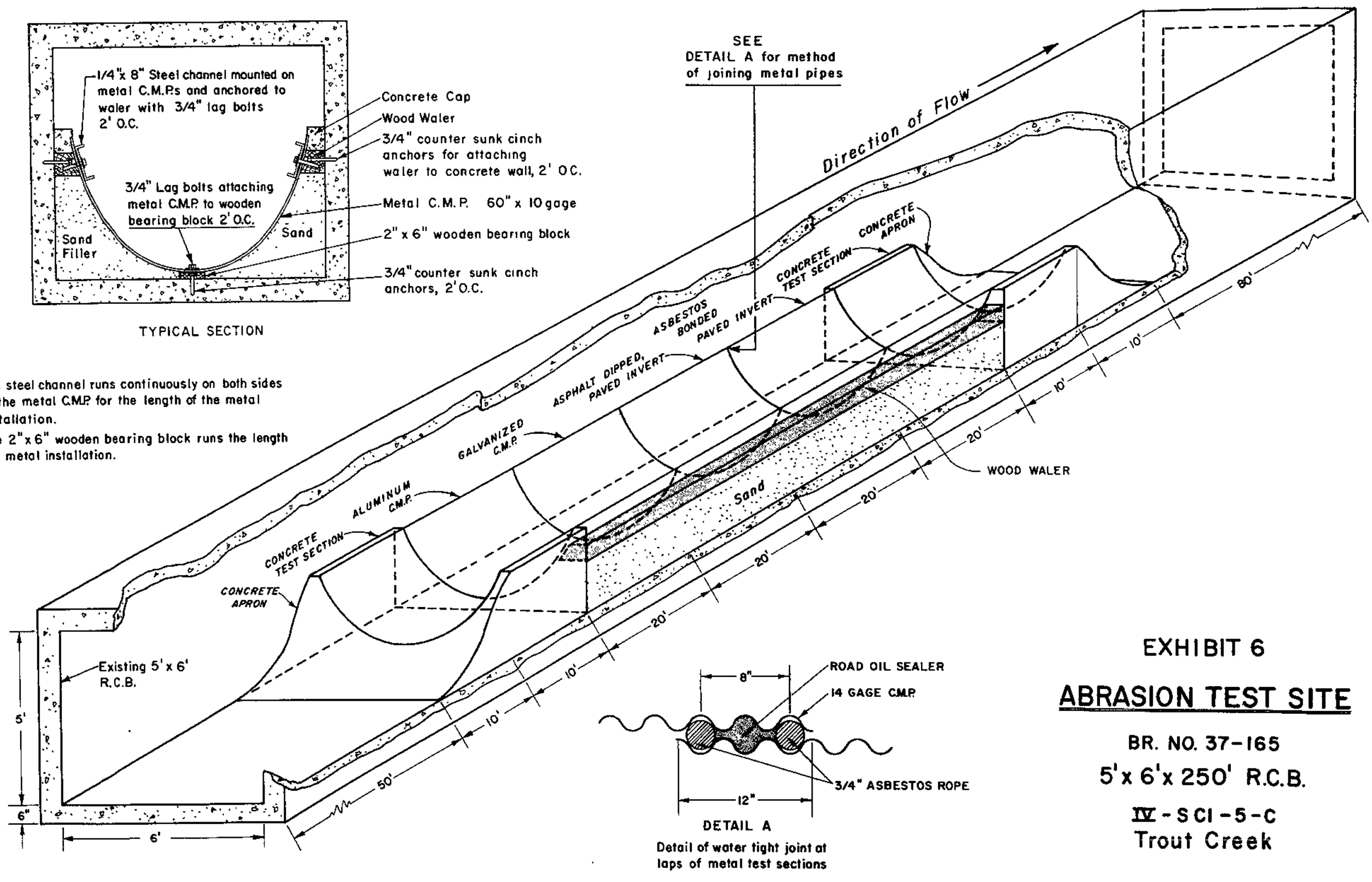


Note irregularities
of concrete floor
under waler.

IV-SC1-5-C
Sta. 250+25
Br. #37-165

Upstream view of jetting sand backfill under completed sections of metal CMPs.

Upstream view of completed installation in RCB. Concrete apron starts inside RCB approx. 50' from entrance.




Note:
1. The steel channel runs continuously on both sides of the metal C.M.P. for the length of the metal installation.
2. The 2" x 6" wooden bearing block runs the length the metal installation.

EXHIBIT 6

## ABRASION TEST SITE

BR. NO. 37-165

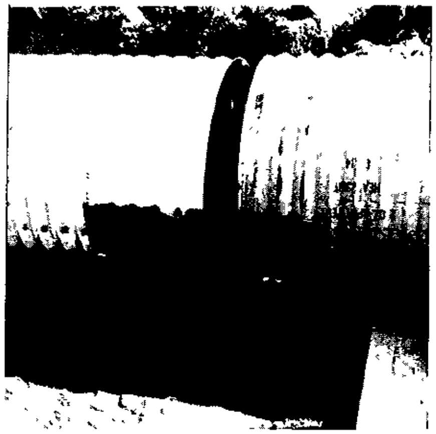
5' x 6' x 250' R.C.B.

IV - SCI - 5 - C

Trout Creek

X-SJ-53-C
40' ± Rt. of Sta. 6±

EXHIBIT 7



Placing neoprene gasket and lower section of coupler

Placing top section of coupler

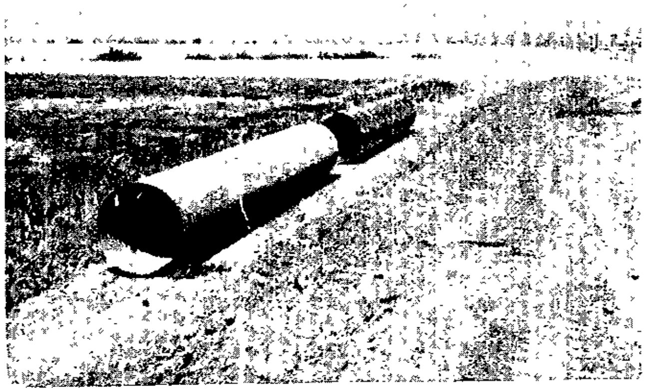
Heavy equipment pulling a hand operated scoop through ditch.

Lowering pipes into ditch with rope.

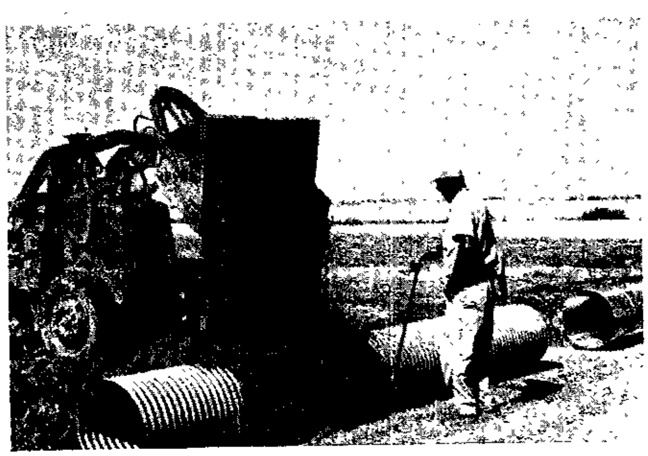
Backfilling over piping

Completed installation

Obtaining backfill material in field adjacent to CMP installation

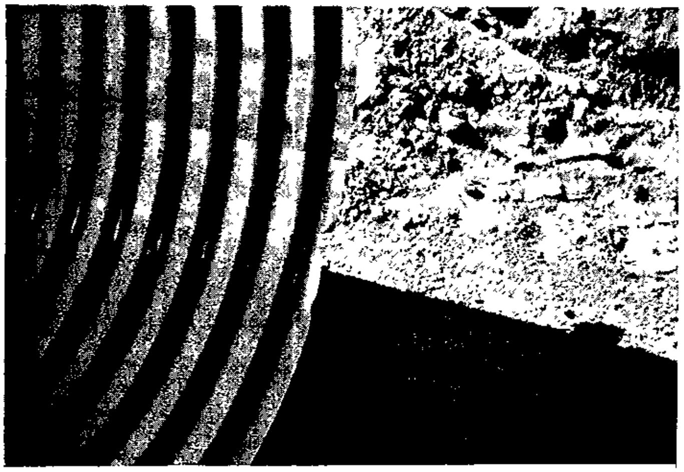


Pipes separated approximately 5' and placed in ditch, ready for backfill. The pipes were not connected with a coupler.



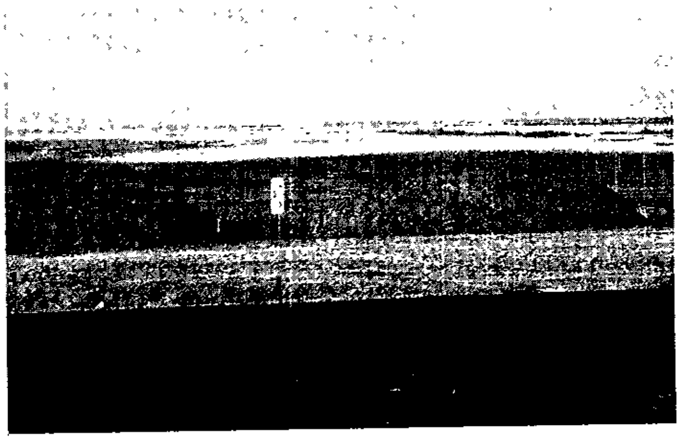
Backfilling over the galvanized CMP

XI-Imp-187-F
50' ± Lt. of Sta. 498±



Note damaged end of aluminum CMP due to handling.

Compacting backfill over CMP.

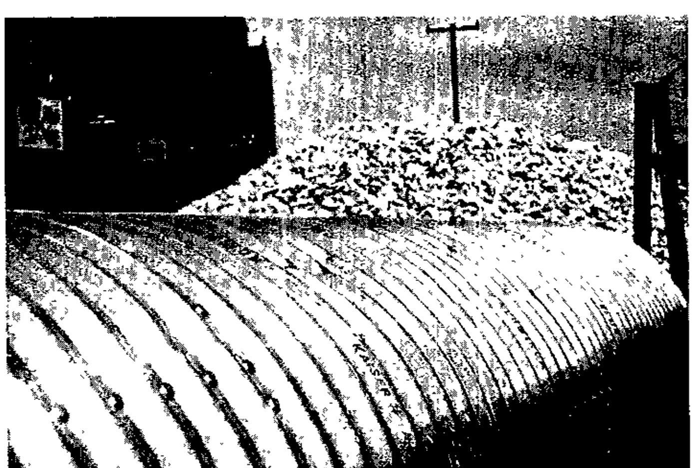


Completed installation.

XI-SD-2-Nat. City
Approx. 20' Lt. of
Bent 5 of Br. #57-245,
Sweetwater Creek

Excavation along bank of Sweetwater River for CMP installation.

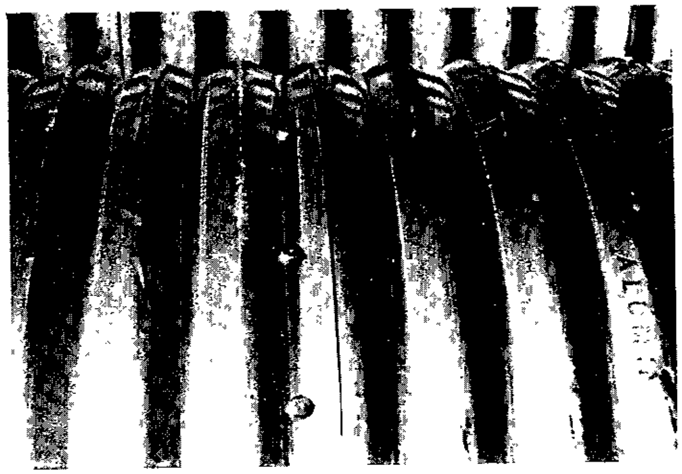
Excavating area for CMP installation.



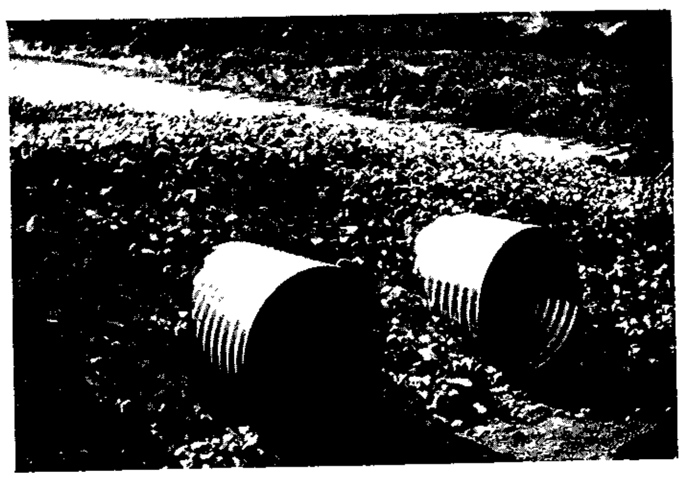
Note damaged areas on aluminum CMP due to handling.

XI-SD-2-Nat. City
Approx. 20' Lt. of
Bent #5 of Br. #57-245,
Sweetwater Creek

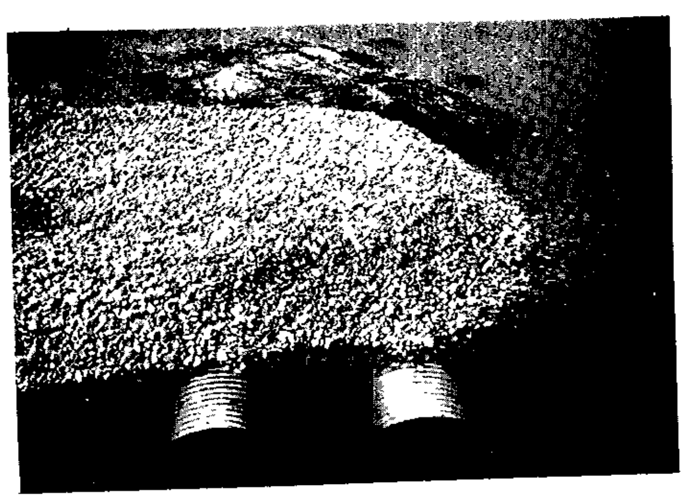
EXHIBIT 11



Note damaged surface of alum. CMP due to handling



End view of completed installation at low tide.



View of completed installation taken from Sweetwater Cr. Br. #57-245-L at high tide.

II-Sha-3-B
Rt. of Sta. 265

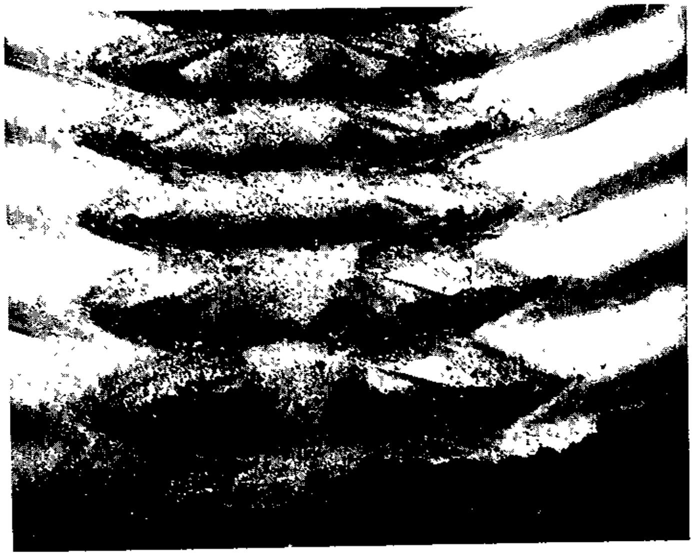
EXHIBIT 12

This sample was taken from the invert of alum. CMP after 56 days of acid exposure. Invert perforated at 157 days of exposure.

II-Sha-3-B
Rt. of Sta. 265



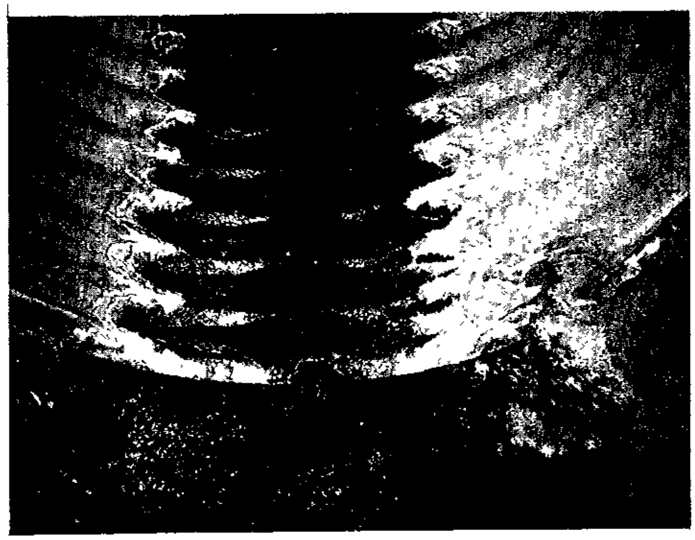
Galvanized CMP after 157 days of acid exposure. Invert not perforated.



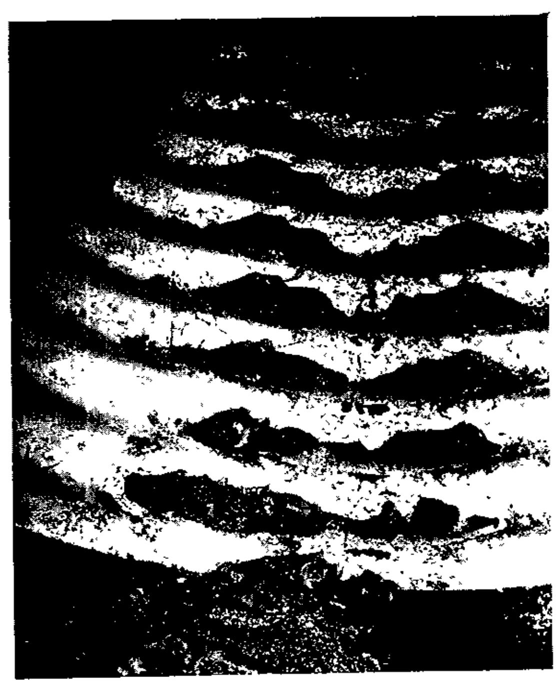
Alum. CMP after 157 days of acid exposure.

Note: Perforations on invert of alum. CMP.

III-But-21-B
Rt. of Sta. 594±



Galvanized steel CMP after 266 days of acid exposure. Invert perforated.



Aluminum CMP after 266 days of acid exposure. Invert perforated.

IV-SC1-5-C
Sta. 250+25.
Br. #37-165

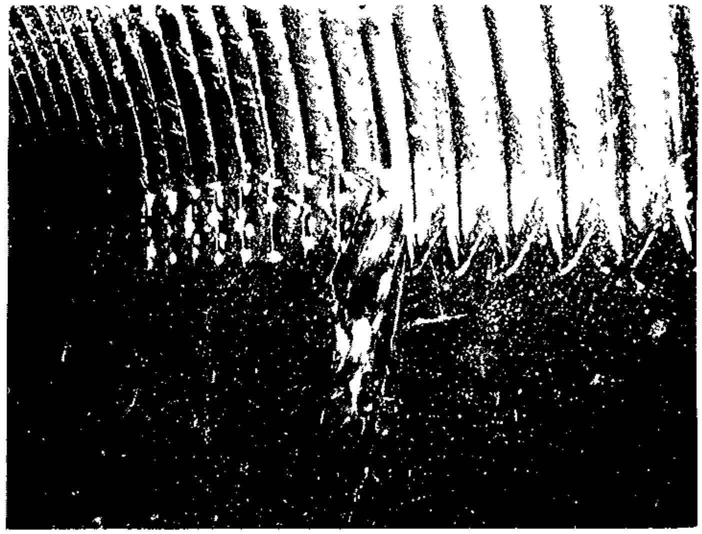
187 days of abrasive exposure

Upstream end of test site. Concrete apron abraded approximately 0.5 inches in depth.

Note abrasion of aluminum rivets and denting of the surface of the pipe.

Invert of galvanized steel CMP.

Note: Anchor bolt and rivets.



187 days of abrasive exposure

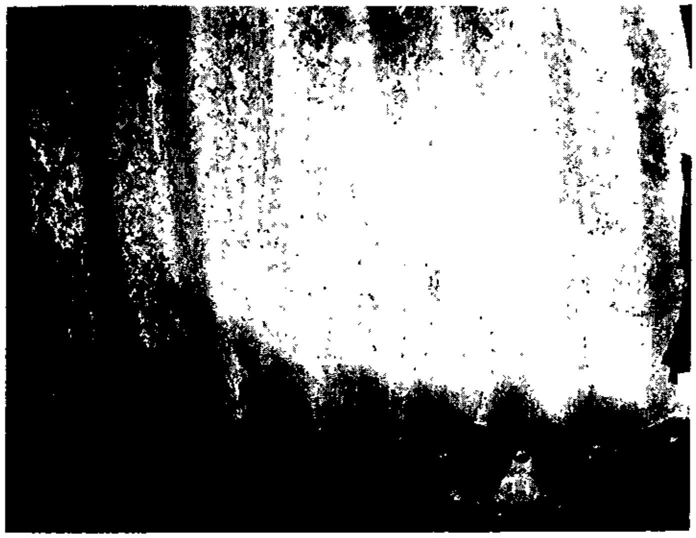
Bottom and side of asphalt dipped paved invert pipe. Note chipping of asphalt above paved invert. Paving is intact.

Invert of asbestos bonded paved invert pipe and concrete test section at downstream end of test site. Concrete abraded approximately 0.5 inches in depth.

Invert of asbestos bonded paved invert pipe. Paving is intact. Note: anchor bolt.

XI-SD-2-Nat. City
Approx. 20' Lt. of Bent #5
Br. #57-245. Sweetwater Cr.

EXHIBIT 17



215 days of exposure.

Aluminum CMP. Minor pitting of surface.

Galvanized steel CMP. Galvanizing is intact.